

ASSESSMENT OF BLENDING LOCAL AND IMPORTED AGGREGATES ON PROPERTIES OF THEIR ASPHALT CONCRETE MIXTURES

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ABSTRACT

Environmental conditions in the State of Qatar together with lack of good-quality aggregates seem to severely reduce the service lives of constructed pavements. The current practice of road construction agencies in Qatar is to utilize Marshall method of mix design to arrive at the best combination of aggregates, commonly crushed local limestone or imported Gabbro as coarse and fine aggregates and a mineral filler, and the 60/70 pen. grade bitumen. Little effort was undertaken to investigate the possibility of blending the local limestone and imported Gabbro aggregates and/or utilizing a harder bitumen grade, such as the 40/50 pen., to improve the properties of produced asphalt concrete mixtures.

The main objective of this study is to assess the effect(s) of using a blend of 50% Gabbro, 50% limestone as an aggregate on the performance of the respective bituminous concrete mixtures utilizing the 40/50 and 60/70 pen. grade asphalt cements as binders, respectively.

Results of the study indicate that a better Marshall stability could be obtained by blending limestone and Gabbro aggregates. However, the 40/50 pen. concrete mixtures did not exhibit superior qualities to those of the commonly used 60/70 pen. Asphalt concrete mixtures utilizing Gabbro aggregates alone showed better mix density and were less affected by water soaking.

INTRODUCTION

Qatar, as all other Arabian Gulf states, is located in a dry desert area. Ambient temperature is generally high, specially during summer months. Moreover, humidity and solar radiation have severe effects on asphalt concrete pavements. These harsh weather conditions together with inferior aggregates, in some cases, reduced to a great extent the intended service lives of pavements.

The common coarse and fine aggregates locally used in preparing road mixes are either the local crushed limestone or crushed Gabbro imported from the Emirates and/or Oman. The 60/70 pen. grade bitumen imported from Saudi Arabia is commonly specified as a binder in the asphalt concrete mixtures.

Few studies were undertaken to investigate the possibility of using a blend of the local limestone and imported Gabbro aggregates to improve the properties of produced asphalt concrete mixtures. Data available from a previous study (1) indicate that the use of a hard grade of bitumen, such as the 40/50 pen., may improve the performance of their concrete mixtures in hot climates, mainly higher stability and less flow.

The main objective of this study is to assess the effect(s) of using a blend of 50% Gabbro, 50% limestone as an aggregate on the performance of the respective bituminous concrete mixtures utilizing both the 40/50 and 60/70 pen. grade asphalt cements as binders.

The scope of this study comprises of collecting data on previous work, followed by investigating the properties of local asphalt concrete mixtures utilizing Gabbro and/or limestone as an aggregate. Two grades of binder were employed in this investigation, namely; the 60/70 and 40/50 pen. grade asphalt cements. Furthermore, specimens prepared at the design binder content for the different aggregate-asphalt mix alternatives were tested after 30 min. and 24 hours soaking in a water bath maintained at 60 °C to assess the changes in Marshall test properties due to possible effects of water .

REVIEW OF PREVIOUS WORK

Results of a series of physical and mechanical tests carried out on some locally-produced limestone aggregates as well as imported "Gabbro" aggregates are shown in Table 1 (2).

Clearly, the Gabbro, in general, shows better resistance to wear and less water absorption (11.9% and 0.6% compared to 23.3% and 1.3% for the local crushed limestone aggregate samples, respectively). The porous nature of local limestone aggregates is evident as the water absorption percent reached 3.7% in some samples, exceeding the 2.2% maximum limit specified in QNBS (3).

Results of the 10-min. immersed rotational test (IRT) shown in Table 1 indicate that limestone samples, in general, did not satisfy QNBS for the loss

Table 1: Summary of Results of Some Previous Tests Performed on Local and Imported Aggregates (2).

Test / Property	Limestone ⁽¹⁾		Gabbro ⁽²⁾		QNBS Limits
	Range	Distribution Mean	Range	Distribution Mean	
Flakiness (%)	7 - 30	12	11 - 33	12	Max. 30%
Elongation (%)	5 - 30	24	10 - 33	24	Max. 30%
Specific Gravity					
- Oven-Dried	2.553 - 2.758	2.646	2.846 - 2.944	2.891	-
- Saturated-Surface Dried	2.631 - 2.782	2.681	2.870 - 2.955	2.909	-
- Apparent	2.670 - 2.852	2.747	2.833 - 2.982	2.920	-
Bulk Density (kg/cu. m.)					
- Loose	1286 - 1403	1343	1409 - 1579	1491	-
- Rotted	1449 - 1535	1500	1581 - 1729	1645	-
Water Absorption (%)	0.4 - 3.7	1.3	0.4 - 0.8	0.6	Max. 2.2%
Los - Angeles Value (%)	19.7 - 26.2	23.3	11.9	11.9	Max. 30%
IRT ⁽³⁾ Loss (%)	5.9 - 21.3	11.4	5.0 - 7.2	5.8	Max. 10%
ACV ⁽⁴⁾ (%)					
- Standard	20.4 - 22.3	21.4	-	15.8	Max. 25%
- Soaked	21.4 - 23.5	22.5	-	17.6	-
10% Fines (kN)					
- Standard	164 - 191	175	-	311	-
- Soaked	145 - 171	155	-	248	-
- Difference	16 - 27	20	-	63	Max. 50 kN
Soundness (%)	0.8 - 3.6	2.1	-	0.4	Max. 10%
Sulfate Content (%)	0.04 - 1.10	0.28	0.04 - 0.12	0.08	Max. 0.4%
Chloride Content (%)	0.02 - 0.11	0.04	0.01 - 0.03	0.01	Max. 0.1%

(1) Based on 20 samples.

(3) Immersion-Rotational Test.

(2) Based on 7 samples.

(4) Aggregate Crushing Value.

factor (11.4% , exceeding the 10% maximum limit specified in QNBS). Also, the acidic nature of some limestone aggregate samples are implicitly indicated by results of tests of sulfate and chloride contents. For instance, the

0.4% maximum sulfate content specified in QNBS was well exceeded for some limestone aggregate samples and values as high as 1.1% were experienced.

Table 2 summarizes the results of another study (4) on Marshall test properties of asphalt concrete mixtures utilizing limestone, slag and Gabbro aggregates and 40/50 and 60/70 pen. grade bitumens. Results in this table show little differences between Marshall test properties of 40/50 and 60/70 pen. grade asphalt concrete mixtures, respectively. The only major difference was the optimum binder content for limestone mixtures (5.3 compared to 5.8% for the 60/70 and 40/50 pen. grade bitumens, respectively). Slag and Gabbro mixtures showed higher stability values with the 40/50 pen. bitumen. Improved skid resistance, particularly in the wet condition, was recorded for mixtures containing Gabbro aggregates and 40/50 pen. bitumen (4).

Table 2: Comparison between Marshall Test Properties at Optimum Binder Contents (4)

Property	60/70 Pen Grade Bitumen			40/50 Pen. Grade Bitumen		
	Limestone	Slag	Gabbro	Limestone	Slag	Gabbro
Specific Gravity	1.034	1.020	1.029	1.027	1.027	1.029
Optimum Binder Content, %	5.3	6.2	4.9	5.8	6.3	4.8
Stability, kN	13.0	14.9	13.2	10.6	15.2	13.5
Flow, mm.	4.2	5.1	4.9	4.0	5.6	4.9
Air Voids, %	2.8	4.0	2.8	2.7	4.5	3.0
Voids Filled Bitumen, %	80.0	79.0	81.0	81.0	76.0	78.0
Maximum Density, t/m ³	2.415	2.645	2.502	2.398	2.635	2.490

MATERIALS

In this study, crushed Gabbro and/or limestone were used as coarse and fine aggregates in the asphalt concrete mix design. Gradation of these materials were

chosen so as to satisfy the limits specified by QNBS for wearing course mixtures (3). Two penetration grades of asphalt were employed in the study, namely; 40/50 and 60/70. Ordinary Portland cement (2% by total weight) was used as a filler in the asphalt concrete mixtures. Results of tests performed on all these materials conformed with the limits specified in QNBS. Number of blows used in compacting Marshall test specimens was 75 for all the investigated mixtures.

TEST RESULTS AND DISCUSSION

Table 3 presents a summary of results of Marshall tests performed on the various asphalt concrete mixtures included in the experimental program of this study to cover all the shown aggregate-type and asphalt-grade combinations (2 bitumen grades x 3 aggregate types x 3 replicates = 108 specimens). Also, Figures 1 through 6 compare between the different properties of the alternate asphalt concrete mixtures.

Table 3 - Summary of Marshall Test Properties at Optimum Binder Content

Description	60/70 Pen. Grade Bitumen			40/50 Pen. Grade Bitumen			QNBS Limits
	L ⁽¹⁾	G ⁽²⁾	(L+G) ⁽³⁾	L	G	L + G	
Optimum Binder Content (OBC), %	5.33	4.73	4.9	5.37	4.83	5.3	4 - 5.5%
Mix Density, t/m ³	2.42	2.665	2.53	2.48	2.662	2.532	-
Stability, kN	18	18	20.8	18.0	16.8	18.4	Min. 8
Flow, mm.	3.3	3.1	3.4	3.4	3.4	3.9	Max. 4
Air Voids, %	3.3	3.1	3.9	3.9	3.4	3.4	3 - 5
Voids Filled Bitumen, %	75	77	74	77	75	76	70 - 80

- (1) Crushed limestone aggregate.
- (3) 50% limestone + 50% Gabbro.

- (2) Crushed Gabbro aggregate.

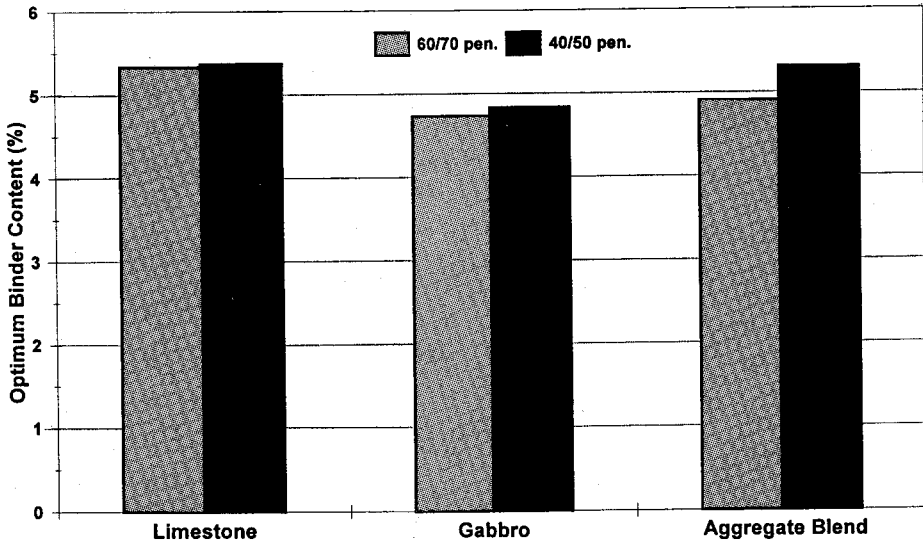


Fig. 1: Optimum binder content vs. type of aggregate and grade of bitumen

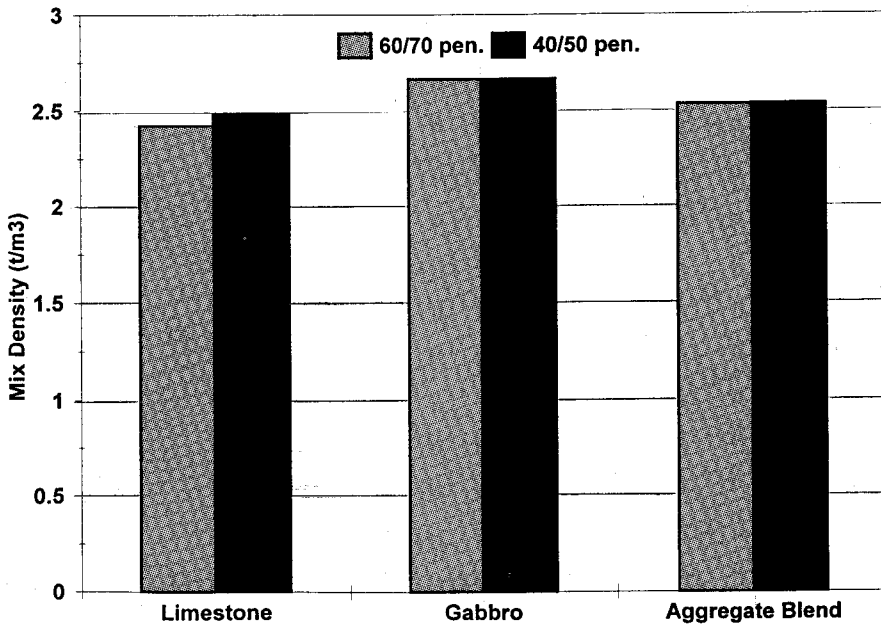


Fig. 2: Mix density vs. type of aggregate and grade of bitumen

Assessment of Blending Local and Imported Aggregates

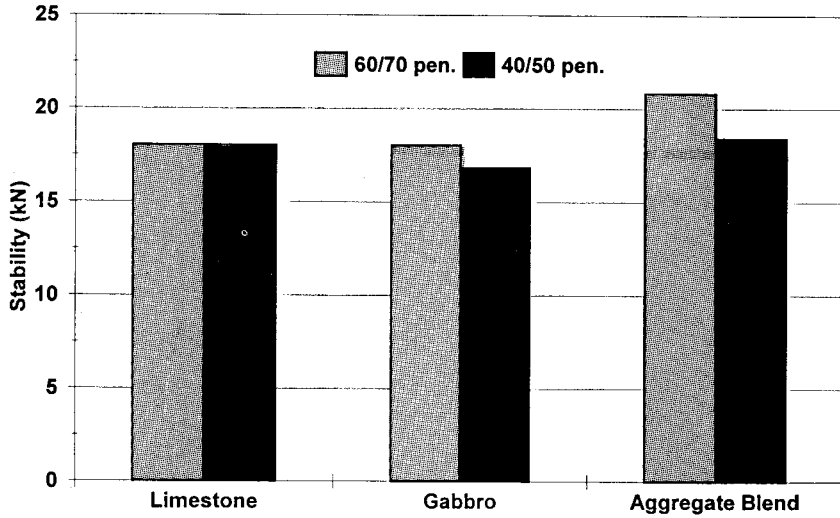


Fig. 3: Marshall stability vs. type of aggregate and grade of bitumen

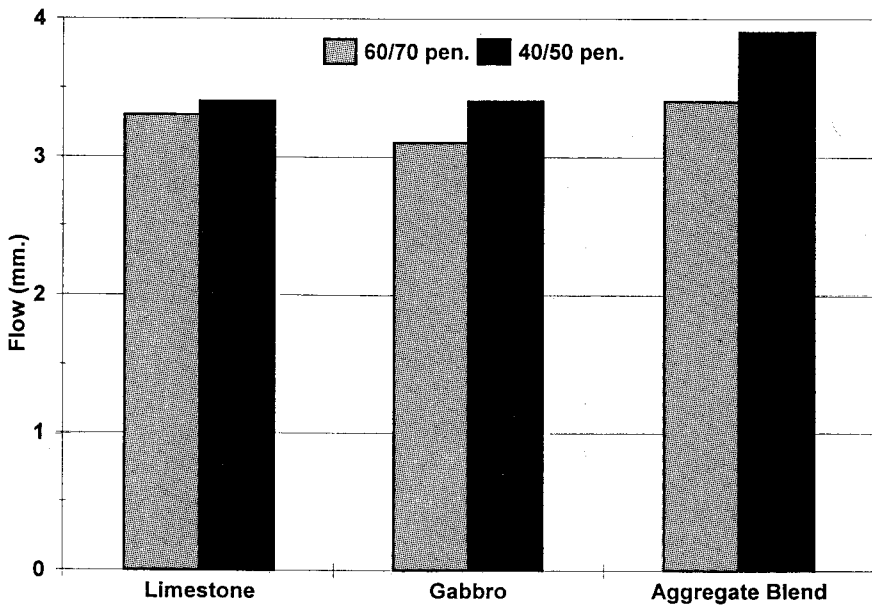


Fig. 4: Marshall flow vs. type of aggregate and grade of bitumen

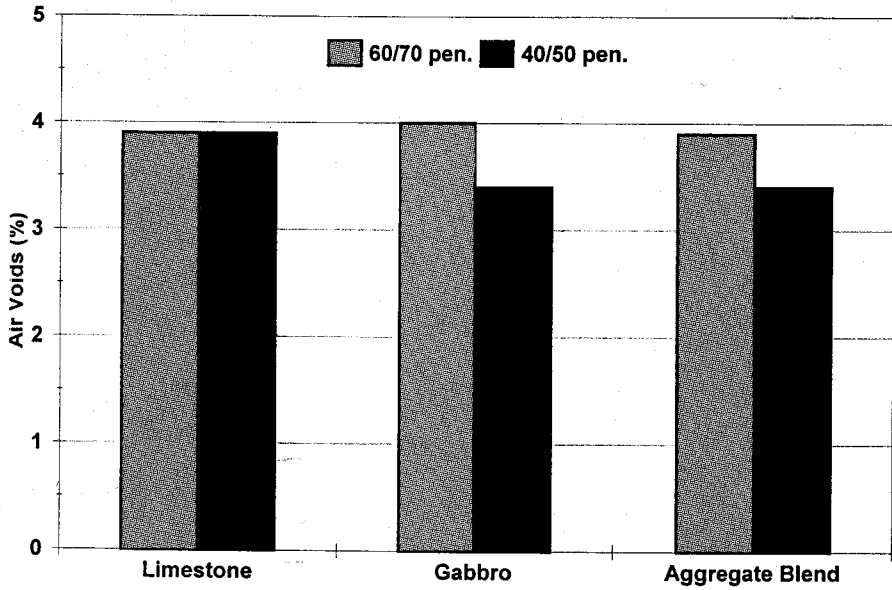


Fig. 5: Percent air voids vs. type of aggregate and grade of bitumen

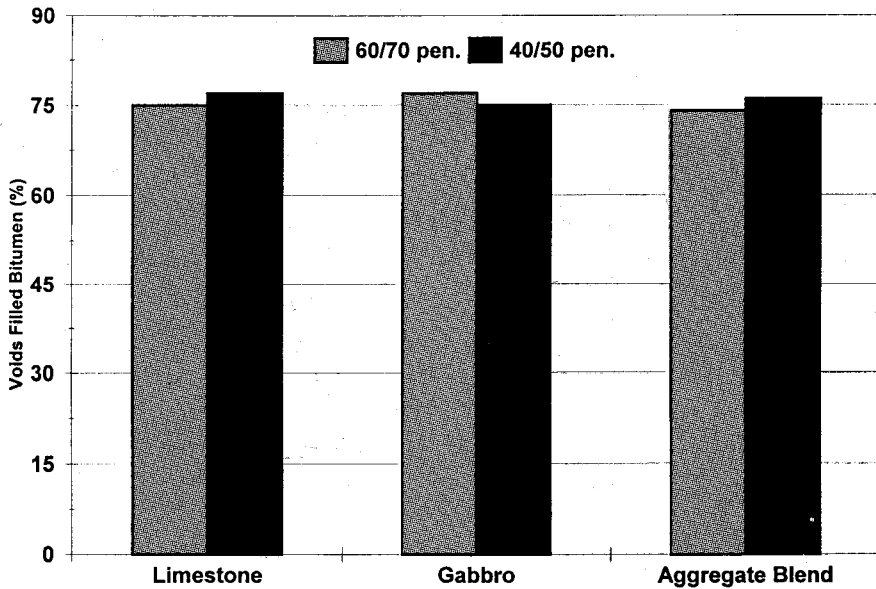


Fig. 6: percent voids filled bitumen vs. type of aggregate and grade of bitumen

Optimum Binder Content (OBC)

The lowest binder contents were those of the Gabbro-asphalt concrete mixtures (4.73 and 4.83%, for the 60/70 and 40/50 pen. grade bitumens, respectively). On the other hand, the highest reported values were experienced with the limestone mixtures (5.33 and 5.37% for the 60/70 and 40/50 pen. grade bitumens, respectively). This finding may be expected because of the rather porous nature of limestone aggregates, as compared to that of the Gabbro. Minor differences can be detected between the OBC for asphalt concrete mixtures utilizing the 40/50 or 60/70 pen. grade asphalt, except for the combined aggregate grading (L+G) as the difference reached 0.4%.

Marshall Stability

Results in Table 3 indicate that the higher stability values were experienced with the combined aggregate gradation (20.8 and 18.4 kN for the 60/70 and 40/50 pen. grade asphalt binders, respectively). A slight difference was evident between the stability values of the 40/50 pen. asphalt concrete mixtures (18 compared to 16.8 kN for the limestone and Gabbro mixtures, respectively).

Marshall Flow

No remarkable differences was found between the flow values of the respective mix alternatives. The lowest flow value (3.1 mm.) was found for the Gabbro aggregate and 60/70 pen. grade asphalt concrete mixtures and the highest (3.9 mm.) for the combined aggregate with the 40/50 pen. grade asphalt.

Mix Density

Mix density values of Gabbro mixtures were generally higher than those of both limestone and combined aggregate concrete mixtures (2.665 and 2.662 t/m³ for 60/70 and 40/50 pen. asphalt concrete mixtures, respectively). On the other hand, the lowest values were recorded for limestone concrete mixtures (2.42 and 2.48 t/m³ for 60/70 and 40/50 pen. asphalt concrete mixtures, respectively). This finding may be attributed to the effect of the higher specific gravity of Gabbro aggregate, as compared to that of limestone. Again, density values of 40/50 pen. grade asphalt concrete mixtures did not differ much from those of the 60/70 pen.

Effect of Water

For the purpose of this phase of the study, new asphalt concrete specimens were prepared. Asphalt content in all cases was the optimum as determined in the previous phase of this study. Table 4 presents a comparison between Marshall stability values of the different aggregate type and asphalt grade mixture alternatives. Retained stability is defined as the percent of Marshall stability after 24 hours to that after 30 min. soaking periods, respectively. Temperature of the water bath was maintained at 60 °C during both soaking periods.

Results shown in Table 4 indicate that Gabbro mixtures exhibited the highest retained stability values (92.7 and 97% for the 40/50 and 60/70 pen. grade asphalt concrete mixtures, respectively). These values are compared to 82.9 and 86.3% for the limestone mixtures.

Table 4: Comparison between Marshall Stability of Mixtures Immersed in Water for 30 min. and 24 Hours

Aggregate Type	Stability after 30-min., kN	Stability after 24-hr., kN	Difference, kN	Retained Stability, %
40/50 Pen. Grade Bitumen				
Limestone	19.43	16.11	3.32	82.91
Gabbro	18.59	17.24	1.35	92.74
Combined Aggregate	21.28	18.27	3.01	85.86
60/70 Pen. Grade Bitumen				
Limestone	20.28	17.50	2.78	86.29
Gabbro	16.73	16.22	0.51	96.95
Combined Aggregate	22.20	18.96	3.24	85.41

This result may be expected because of the lower water absorption characteristic of the igneous Gabbro rock in comparison with the sedimentary limestone. In general, results also indicate that retained stability values of the 60/70 pen. asphalt concrete mixtures were marginally higher than those of the 40/50 pen.

whatever was the aggregate type (86.3 compared to 82.9 % and 97 compared to 92.7% for the limestone and Gabbro mixtures, respectively).

Table 5 presents a comparison of Marshall flow values for the same mix alternatives. Limestone mixtures showed minor percent increases in their flow values after 24 hours immersion in water (5.9 and 2.9% for the 40/50 and 60/70 pen. asphalt concrete mixtures, respectively). The other aggregate type-asphalt grade mixture alternatives did not show consistent trends.

Table 5: Comparison between Marshall Flow of Mixtures Immersed in Water for 30 min. and 24 Hours

Aggregate Type	Flow after 30-min., mm.	Flow after 24-hr., kN	Difference mm.	Difference %
40/50 Pen. Grade Bitumen				
Limestone	3.4	3.6	0.2	+ 5.88
Gabbro	3.2	3.1	0.1	- 3.13
Combined Aggregate	3.8	3.6	0.2	+ 5.26
60/70 Pen. Grade Bitumen				
Limestone	3.4	3.5	0.1	+ 2.94
Gabbro	3.0	3.4	0	0
Combined Aggregate	3.4	3.4	0	0

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- a) Previous studies indicate that imported Gabbro aggregate samples showed higher specific gravity, less water absorption and less percent wear than those of the locally-produced limestone aggregate samples.

- b) Optimum binder contents (OBC) of Gabbro-asphalt concrete mixtures were generally less than those of limestone and combined aggregate blend (50% limestone + 50% Gabbro) concrete mixtures.
- c) Results did not indicate significant differences between the OBC for the 40/50 and 60/70 pen. asphalt concrete mixtures.
- d) Asphalt concrete mixtures utilizing the combined aggregate and either the 40/50 or the 60/70 pen. grade asphalt cement exhibited the highest stability values.
- e) No marked differences existed between the measured stability values of Gabbro and limestone mixtures utilizing the commonly used 60/70 pen. grade asphalt cement. This finding matches the result of the Materials Lab of the MMAA (4).
- f) No clear trend was found for Marshall flow values of the different aggregate type-asphalt grade mix alternatives.
- g) Gabbro-asphalt concrete mixtures yielded the highest density values at the OBC. This result can be attributed to the high specific gravity of such aggregate. The same finding was reported in the study of the Materials Lab of the MMAA (4).
- h) The highest retained stability values after 24-hr. soaking in 60 °C - water bath were found for Gabbro asphalt concrete mixtures. The 60/70 pen. asphalt concrete mixtures, in general, exhibited better retained stability values, as compared to those of the 40/50 pen.

Recommendations

- a) Further experimental work is recommended to be undertaken utilizing larger sample size, different limestone aggregate sources, different aggregate blending ratios (limestone to aggregate) and different number of blows.
- b) Results of the recommended experimental work should be correlated with actual field performance of in-situ test sections constructed with the same respective aggregate type and/or asphalt grade mix alternatives. A rutting test would be useful for this purpose.

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